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(56) Documents Cited
GB 2243682 A **EP 0195161 A2** **EP 0129751 A2**
WO 84/01212 A1 **US 5157762 A**

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(54) **Detecting manufacturing errors in an article**

(57) Manufacturing errors in an article are detected by comparing an image of the article with a theoretical image generated by a computer aided drafting system and identifying any differences between the two.The images may be video images, photographic images, holograms or constituted by data held electronically. A laser interferometry fringe pattern is formed representing the shape of the article and compared to an ideal interferometry fringe pattern generated by software linked to the CAD software.

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A METHOD OF DETECTING MANUFACTURING ERRORS IN AN ARTICLE

This invention relates to a method of detecting manufacturing errors in an article whereby the size and shape of the actual article are compared with the theoretical design thereof. It is particularly, but not exclusively, concerned with a method of inspecting an article such as a cast metal component and has special application for use with gas turbine blades.

A component such as a gas turbine blade may be required to have a complicated surface contour and for optimum operational efficiency will need to be manufactured to extremely fine tolerances.

To check that such components are actually within their design limits is a difficult, time-consuming and expensive task which requires specialist measuring and inspection equipment and highly trained staff.

The object of the invention is to provide a quicker, cheaper and more accurate method of detecting manufacturing errors in an article.

To that end, a first aspect of the invention provides a method of detecting manufacturing errors in an article wherein the article is compared with its theoretical design, the method comprising the following steps:

i) forming a first image, being an image of the manufactured article;

ii) utilising a computer aided drafting system to provide a second image, being an

image of the theoretical design of the article;

iii) comparing the first image and the second image;

iv) identifying any differences between the first image and the second image.

The term 'image' is to be interpreted generally in this context. The first image may comprise a photographic image, an image on a visual display unit, a hologram or may be in the form of data held electronically which is fully descriptive of the article. The second image may likewise take any appropriate form (including any of the forms exemplified for the first image). Of course, the two images will need to be in forms compatible for comparison purposes.

In a preferred embodiment step (i) includes the step of mounting the manufactured article and illuminating the article to produce a pattern on the surface of the article; the article may be illuminated using a laser interferometry technique which produces a fringe pattern on the surface of the article and the illuminated article may be viewed via an optical device with the first image including the pattern.

The second image may be formed by virtually illuminating a theoretical model of the article as provided by the computer aided drafting system. The virtual illumination of the model may utilise software emulating an electronically generated laser and such software may be designed to give an idealised fringe pattern on the model.

In a preferred realisation step (iii) includes the step of bringing the first image and the second image into the same perspective and attitude by the use of selected datum points on said first and second images and step (iii) may further include the step of electronically comparing

the differences in the fringe patterns.

In step (iv) computer software may be utilised to describe the differences between the first image and the second image in a visual form or a numerical form.

According to a second aspect of the invention, a method of detecting manufacturing errors in an article, comprises the steps of:

i) forming a laser-interferometry fringe pattern representing the theoretical three-dimensional shape of a portion of the article, which shape is provided by a computer aided drafting system,

ii) forming a corresponding laser-interferometry fringe pattern representing the actual three-dimensional shape of the corresponding portion of the manufactured article, and

iii) comparing the respective fringe patterns to determine departures of the shape of the manufactured article from its theoretical design.

An embodiment of the invention will now be described, such embodiment being purely exemplary of various ways in which the invention may be put into effect.

For convenience, the remainder of the description will be especially related to a method of detecting manufacturing errors in a gas turbine blade but such should be taken as purely exemplary of the items, articles and components to which the method of the invention is applicable.

The design process of components such as gas turbine blades will involve mathematical calculations, experimentation and, in the final analysis, compromise between conflicting criteria.

Nowadays the design process will almost certainly involve, to a greater or lesser extent, use of a computer aided drafting system (hereinafter referred to as CAD System) and the present invention utilises such a system as one of its features. However the final theoretical design of an article is arrived at, details of that final design i.e. shape, angles, dimensions, curvatures, etc. will be defined in the memory of the CAD system. Furthermore, machinery used for making the component will often rely on the CAD system data for instruction and control of the machinery.

By virtue of the data held, a three dimensional model is generated and held in the CAD system showing full details of the theoretical design, and this three dimensional model is utilised for comparison with the actual manufactured component. It is to be appreciated that the three dimensional model exists in the form of computer held data but it is visible on a VDU or as a print from the VDU; it is of course viewable on the VDU from any angle or position and may be scaled as required. As part of the detection process a fringe pattern is to be formed on the image of the theoretical design and, since this is the idealised design, so too will the fringe pattern be idealised. To form a fringe pattern on the model, additional software linked to the CAD software is utilised. The additional software, in fact, acts to emulate a laser interferometry technique on the model and overlays on the model the idealised fringe pattern. This overlay may be visible on the VDU (or a print therefrom) but this is not essential as long as the computer has the fringe co-ordinates for comparison with the fringe pattern formed on the real turbine blade (see below).

The details of the actual manufacture of the component are of no relevance to the

invention but, by way of example, it is envisaged that the blade would be cast using e.g. an investment casting technique.

The component in its final manufactured form is mounted and is then illuminated using an appropriate technique, whereby a fringe pattern is produced on the surface of the component. Various methods are available for the formation of such a fringe pattern although it will be generally appropriate to use some form of laser interferometry technique.

For example, the manufactured article may be illuminated by one laser source and then by a second laser source, the two sources being spaced apart by a small amount. In fact, this effect is achievable by reflecting the beam from a source onto the article using a tiltable mirror which is tilted between exposures so that the source appears to move.

In an alternative arrangement the article is mounted inside a cell with a fluid therearound whose refractive index is changed between exposures

The fringe pattern identifies changes in gradient on the surface of the component and hence its shape.

The illuminated shape is viewed via an optical device, e.g. a camera, and the image seen including the associated fringe pattern is recorded in any appropriate form, e.g. as a hologram, as a photograph, as a video image or electronically.

For the comparison between the fringe patterns of the CAD model and the real

component to be properly undertaken it is essential that both be exactly to the same dimensional scale and both be placed in exactly the same attitude, orientation and perspective. To achieve this, equivalent datum points will be applied to both the computer model of the theoretical design and the image of the real component. (Datum points selected may, for example, be points formed by the intersection of two or more surfaces). The CAD model is then scaled and rotated until an exact match of the datum points of the CAD model and the equivalent datum points on the image of the real component is obtained.

When the CAD model and the image of the real component have been thus overlaid the fringe patterns are compared. Any differences between the fringe pattern indicate an error in the manufacture of the real component and the error can be computed due to the known wavelength of the laser light utilised.

Having detected any differences between the two representations, the various deviations of the actual shape from the idealised shape may be reproduced in a visual or numerical form by use of suitable software.

The decision may then be taken as to whether the actual component is within design tolerances or whether the design tolerances are exceeded to the extent that the component must be rejected, or sent for re-manufacture

CLAIMS

1. A method of detecting manufacturing errors in an article wherein the article is compared with its theoretical design, the method comprising the following steps:

   i) forming a first image, being an image of the manufactured article;

   ii) utilising a computer aided drafting system to provide a second image, being an image of the theoretical design of the article;

   iii) comparing the first image and the second image;

   iv) identifying any differences between the first image and the second image.

2. A method as claimed in Claim 1 wherein the first image is a video image or a photographic image or a hologram or is constituted by data held electronically.

3. A method as claimed in Claim 1 or Claim 2 wherein the second image is a video image or a photographic image or a hologram or is constituted by data held electronically.

4. A method as claimed in any preceding claim wherein step (i) includes the step of mounting the manufactured article and illuminating the article to produce a pattern on the surface of the article.

5. A method as claimed in Claim 4 wherein the article is illuminated using a laser interferometry technique which produces a fringe pattern on the surface of the article.

6. A method as claimed in Claim 4 or Claim 5 wherein the illuminated article is viewed via

an optical device and the first image includes the pattern.

7. A method as claimed in any preceding claim wherein the second image is formed by virtually illuminating a theoretical model of the article as provided by the computer aided drafting system.

8. A method as claimed in Claim 7 wherein virtual illumination of the model utilises software emulating an electronically generated laser.

9. A method as claimed in Claim 8 as appendant to Claim 5 wherein the software emulating an electronically generated laser gives an idealised fringe pattern on the model.

10. A method as claimed in any preceding claim wherein step (iii) includes the step of bringing the first image and the second image into the same perspective and attitude by the use of selected datum points on said first and second images.

11. A method as claimed in Claim 9 wherein step (iii) includes the step of electronically comparing the differences in the fringe patterns.

12. A method as claimed in any preceding claim wherein in step (iv) computer software is utilised to describe the differences between the first image and the second image in a visual form or a numerical form.

13. A method of inspecting a manufactured article substantially as hereinbefore described.

14. A method of detecting manufacturing errors in an article, comprising the steps of:

i) forming a laser-interferometry fringe pattern representing the theoretical three-dimensional shape of a portion of the article, which shape is provided by a computer aided drafting system,

ii) forming a corresponding laser-interferometry fringe pattern representing the actual three-dimensional shape of the corresponding portion of the manufactured article, and

iii) comparing the respective fringe patterns to determine departures of the shape of the manufactured article from its theoretical design.

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1A (AAJF, AAJP, AMAB, AMAX)

Int Cl (Ed.6): G01N 21/88, G01R 31/302, 31/308

Other: Online Database: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2243682 A	(GERBER) page 7 paragraph 2, page 8 paragraph 3	1, 2, 3
X	EP0195161 A2	(BELTRONICS) page 13 paragraphs 2 & 3	1, 2, 3
X	EP0129751 A2	(FUJITSU) page 2 paragraph 2	1, 2, 3
X	WO84/01212	(CONTREX) page 21 paragraph 2, page 9 paragraph 2	1, 2, 3, 10, 12
X	US5157762	(SNIETKA) column 3 paragraph 5	1, 2, 3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.